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Horne —

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OF THE

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Read before the Edinburgh Geological Society on 12th February 1874.
(*Society's Transactions, Vol. II. Part III.*, 1874.)

With the Author's Compts.

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A SKETCH

OF THE

GEOLOGY OF THE ISLE OF MAN.

BY

JOHN HORNE, F.G.S.,

OF THE GEOLOGICAL SURVEY OF SCOTLAND.

Read before the Edinburgh Geological Society on 12th February 1874.

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A SKETCH

OF THE

GEOLOGY OF THE ISLE OF MAN.

The following paper gives some account of observations made by myself in the Isle of Man, during the autumn of 1873. Only a brief outline of the successive formations is now laid before you, as it is my intention to return to the same field, with the aim of gathering more detailed evidence.

Previous Literature on the Subject.

As far back as the beginning of this century several papers were published on the old rocks of the Isle, by Dr Berger,* Mr Wood, and Professor Henslow.† In the second volume of "The Western Isles" Dr Macculloch has some long chapters on the same subject. He describes the schistose rocks, the representatives of the Old Red Sandstone, and the limestone series; but he failed to note the proofs of volcanic action which are to be met with south of Castletown.‡ In 1826 a paper appeared from the pen of Dr Hibbert on the discovery of the fossil elk; and in 1843 Mr Hugh Strickland, F.G.S., read a paper before the Geological Society in which he gives an account of the glacial beds in the north part of the island.§

There are two writers, however, whose names are closely associated with the geology of the island, viz., Professor E. Forbes, F.R.S., and the Rev. J. G. Cumming, M.A., F.G.S. The former examined the superficial deposits, and named the fossils obtained from them. In his well-known paper on "The Fauna and Flora of the British Isles" several allusions are made to the Manx drift-beds, for the purpose of showing their relation to similar deposits in other countries.‖

In 1845 Cumming published the first clear account of "the Palæozoic Rocks of the Island,"¶ and in 1846 there followed his paper on "the Tertiary Formations."** In 1848 his volume on

* Geol. Trans. vol. ii. p. 29.
† Ibid., vol. v. p. 482.
‡ Macculloch's Western Isles, vol. ii.
§ Geol. Soc. Proc. vol. iv. p. 8.
‖ Memoirs of Geol. Survey, vol. i. p. 336.
¶ Geol. Soc. Proc. vol. ii. p. 317.
** Ibid. vol. ii. p. 335.

the Isle of Man appeared, along with detailed maps and sections and lists of fossils, and in 1861 he published a small guide-book, which contains a brief sketch of the geological formations, bringing the account up to date. The following succession was established by him.*

1. Cambro-Silurian, comprising the clay schists and bands of siliceous rocks.

2. Old Red Sandstone, including the Red Sandstone of Peel, and the conglomerates near Castletown.

3. Carboniferous rocks, divisible into three groups,—

a. Lower limestone group.
b. Upper limestone group.
c. Posidonia schist, with its associated trap-tuffs.

His most recent classification of the drift deposits is as follows:—*a.* Boulder clay and erratic blocks. *b.* Drift gravel. *c.* Raised beaches and alluvial deposits.†

The large collection of fossils which Cumming gathered from the Carboniferous rocks and glacial beds forms one of the chief portions of his valuable work. It enabled him to determine with some approach to accuracy the relative ages of the various groups.

In 1866 a joint paper appeared in the "Transactions of the Geological Society," by Professors Harkness and Nicolson, on the Silurian Rocks of the Isle.‡

The Silurian Rocks.

Nearly four-fifths of the Isle are made up of rocks belonging to this formation. A chain of high ground extends from Ramsay to the Calf of Man. This chain, running from north-east to south-west, forms the back-bone of the island, and is approximately the line of strike of the Silurian rocks. These rocks, so far as observed by me, consist of indurated grey slaty shales and flags. In many places they show imperfect cleavage. In Glen Mooar, and on Slieu Dhoo, in the Sulby Glen and its tributaries, and on the top of Snae Fell, the general dip varies from 20° to 40° N. of W. Again, in the south side of the island, in the Silver Burn, at the cliffs near Port St Mary, and on the eastern side of Langness, the general dip is from 30° to 40° E. of S. at a high angle. From these dips it is evident that a well-marked anticline exists in these rocks. Several years ago Professors Harkness and Nicolson pointed out that this axial line runs from Port Erin to Port Mooar, near Maughold Head. The grey slaty shales and flags, which occur on both sides of the

* Guide to Isle of Man, p. 158, *et seq.*
† Guide to Isle of Man, p. 166.
‡ Geol. Soc. Proc. vol. xxii. p. 488.

great anticline, were considered by them to be the equivalents of the Skiddaw slates of Cumberland. They based this conclusion partly on their lithological resemblance, partly on the fact that the beds in the two localities are in the same line of strike, and also on the discovery of *Palæochorda major*, "a fossil very abundant in the Skiddaw slates of Cumberland."

At Douglas Head, and northwards as far as Clay Head, they found certain green slates and porphyries, which they considered to be on the same horizon as the green slates and ash-beds of the Lake country.*

If this correlation be correct, as all the available evidence seems to prove, then it follows that the grey slaty shales and flags of the Isle of Man are of Lower Llandeilo age. They are inferior in position to the Silurian rocks of the south of Scotland.† Lithologically, they are totally different from any part of that series. The green slates and porphyries are, in all probability, of Lower Caradoc age. In this locality there seems to be no break between the two series, for they rest conformably on the grey slaty shales and flags.

Calciferous Sandstone Series.

The beds belonging to this series have been hitherto assigned to the Old Red Sandstone period. They occur in two localities. One portion occupies the coast line for nearly two miles north of Peel; the other fringes the east and north edges of the limestone basin at Castletown. On the east side of Castletown Bay lies the Langness Promontory, a strip of land about a mile and a half long. The Skiddaw slates occupy the outer or seaward edge of this promontory; the beds belonging to the above series lie on the inner side, and at low tide the lower limestones are seen still farther to the west. In no other locality can the relations of the members of this series to the under-lying and overlying rocks be so well studied.

Here they occur in the form of coarse brecciated conglomerates. At Dreswick Point, at the natural arches, and at several places between the Skerranes and Langness farm-house, the unconformity between the conglomerates and the under-lying Silurian rocks is exposed. The old platform on which these breccias were laid down must have been much denuded prior to their formation, for they are to be found filling up pond-shaped hollows in the Skiddaw slates, which makes their thickness very unequal.

Towards the base the conglomerate is chiefly made up of angular fragments of Silurian shales, with occasional blocks of

* Geol. Soc. Proc. xxii. p. 488, *et seq.*
† See Nature, No. 213, vol. ix. p. 58.

white quartz and quartz-rock. Higher up it becomes coarser, and the blocks of quartz and quartz-rock are more abundant.

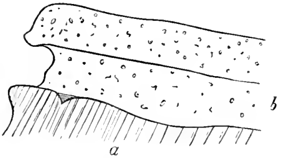


Fig. 1.
a. Skiddaw slates with red discolorations, and showing denuded hollows.
b. Brecciated conglomerate full of angular fragments of Silurian shale, white quartz, and quartz rock.

Its general character is variable. Sometimes it is a mere pell-mell arrangement of subangular stones with scarcely any paste. In other places it consists of blocks of white quartz and quartz-rock embedded in a reddish gritty matrix, while not many yards seawards it passes into a coarse grit and sandstone, with occasional subangular blocks. Several instances occur of large blocks lying in layers of fine sand and brecciated paste, and pressing down the laminæ. The following instance is met with close to the natural arches.*

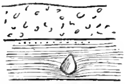


Fig. 2. — Boulder of quartz-rock pressing down the laminæ of sand.

These beds closely resemble the brecciated conglomerates north of Corrie in Arran.

Opposite Langness farm-house, at low tide, the lower limestones are seen resting conformably on the reddish grey breccias. This conformable junction can be traced northwards by Derbyhaven to Cass-ny-Hawin, near the mouth of Santon Burn. The general dip is about 30° N. of W., at an angle of 6° or 8°.

At Cass-ny-Hawin, a fault running 5° N. of W. brings down the limestones against the gnarled shales.

Again, these breccias can be traced forming a thin margin round the north side of the limestone basin. In the Crossag Burn, in the Silver Burn, and in the roadside cutting near Silver Burn farm-house, they may be seen resting unconformably on the Silurian rocks, and passing underneath the lower limestones. At these localities they are not so coarse as the Langness conglomerates, but the included fragments are, as a rule, more angular. Their general character is more like the Calciferous Sandstone breccias on the north shores of the Solway, near the mouth of the Dee.

Cumming mentions one locality where he found fossils in these beds. Close to Rushen Abbey the breccias consist chiefly of blocks of white quartz embedded in a grey calcareous matrix.†

* Professor Geikie previously noticed a similar instance in the breccias of Calciferous Sandstone age near Brodick, Arran.

† See Cumming's "Isle of Man," pp. 44 and 240.

In these he found "the characteristic fossils of the lowest limestone series, as seen elsewhere in this basin, particularly *Orthis Sharpei*."

At Peel the character of these beds is totally different. The conglomerates are absent, and only occasional bands of fine breccia occur along with the red sandstones. These beds occupy a narrow strip about two miles in length and about a mile broad. Towards the south the relation between the red sandstones and underlying schists is obscured by the sandy beach in Peel Bay. At the northern limit, in Will's Strand, the junction between the two formations is well exposed on the cliff. The red sandstones are faulted down against the Silurian rocks. The strike of the former is 8° E. of N., their dip being nearly vertical. They abut against the green Silurian shales, which are considerably altered and crumpled. It is impossible to trace definitely the junction line inland, as the evidence lies hid underneath a thick accumulation of drift. Along the coast line the beds dip as a rule at a high angle from 50°–60°. Near the White Strand the dip is somewhat less. The general direction of the dip is from 20°–40° W. of N.

There is one important feature connected with this patch of red sandstones: it is the occurrence in them of some thin bands of cornstone, which strongly resemble the cornstones of the Calciferous Sandstone series in Scotland. As far back as the beginning of this century these bands were burned for lime, but they are no longer used for this purpose. Cumming found in this cornstone a specimen of *Favosites polymorpha*, a Devonian form, from which he inferred that these beds are truly of Old Red Sandstone age.* My colleague, Mr R. Etheridge, junior, F.G.S., suggests the probability of this specimen being the *Favosites polymorpha* (Phillips), which is the equivalent of *Favosites dubia* of Blainville, a true Devonian coral.† If this be true, then it only proves that some of these characteristic Devonian forms survived the close of the Old Red Sandstone period, and flourished in Lower Carboniferous times.

It is worth noting that these brecciated conglomerates pass conformably underneath the carboniferous limestones, and this we think is presumptive proof that they are of Lower Carboniferous age. In Scotland, where this series is typically developed, no perfect passage has yet been found between beds of true Old Red age and the basement group of the carboniferous rocks.

From these data it is highly probable that the red sandstones, cornstones, and brecciated conglomerates in the Isle belong to the Calciferous Sandstone series. Lithologically, they resemble the members of the same series in Scotland. Nay, further, the

* See Cumming's "Isle of Man," p. 240.

† See Edwards and Haime, "British Fossil Corals," 1850, p. 216.

fact that they contain carboniferous limestone fossils is even more convincing proof that they are of Lower Carboniferous age. Not more than forty miles off, on the Kircudbrightshire coast, there are beds belonging to this series which are in many respects identical with most of the Manx sandstones and breccias. With the former is associated a patch of those contemporaneous traps which are so abundant in this series. Although my colleagues have conclusively proved that in Scotland volcanic action reached a great development in Lower Carboniferous times, yet there are no volcanic products of this age in the Isle of Man.

Many years ago Cumming pointed out that the Langness conglomerates looked like an old boulder clay.* One has only to see "with his own eyes" the beds there exposed to be convinced of the resemblance. I searched for scratched blocks, but found none. The occurrence of blocks of considerable size in finer beds, pressing down the laminæ of sand, leads to the belief that they had been dropped during the accumulation of the sandy layers. This fact is suggestive.

Carboniferous Limestone Series.

The only patch of carboniferous limestone occurs in the south side of the island at Castletown. It occupies but a small part of the whole area of the Isle. The beds lie in a small trough, the axis of which, speaking roughly, runs north and south. It is highly probable that this trough shape takes its origin from the north and south system of flexures, which, as Professor Hull has shown, intervened between Permian and Triassic times.† The whole series may be divided into three groups, which are lithologically distinct:—

1. The lower or Castletown limestone group.
2. The upper or Poolvash limestone group.
3. The Poolvash black marble beds, which lie at the top of the series.

From the bottom to the top not a single bed of sandstone is exposed in the coast sections, which are nearly continuous.

1. *The Lower or Castletown Limestone Group.*

The members of this lower group are well seen in Castletown Bay. As has been already noted, the coarse breccias of Langness pass conformably underneath the limestones on the east side of the bay. Thick beds of limestone rest immediately on the red conglomerates. No beds intervene which might be said

* "Isle of Man," p. 89.

† See Prof. Hull on "The Relative Ages of Physical Features," Quart. Journ. Geol. Soc. vol. xxiv. p. 323.

to correspond to the cement stone group or upper part of the Calciferous Sandstone series in Scotland. From Langness westwards to Castletown harbour at low tide the limestones may be traced, dipping about 20° N. of W. at a gentle angle of 6° or 8°. South of the harbour the beds dip generally in the same direction, but near the Scarlet limekilns they are thrown into a series of small folds. The beds which occur in Derbyhaven, and on the shore northwards as far as Cass-ny-Hawin, are merely a prolongation of those in Castletown Bay.

Again, in the north part of the basin there are two quarries where these lower limestones are at present worked. From the dips it is evident that the beds are swinging round. In the quarry nearest Ballasalla they dip S. 18° W., while still farther to the west the direction is S. 40° W., the angle being from 8°–10°.

Along the western margin of the basin the conglomerates are absent.* From this fact Cumming inferred that a great fault forms the boundary line on that side. There was not sufficient time at my disposal to enable me to examine the evidence on which he based this conclusion. The absence of the conglomerates, however, is not by itself complete evidence, for it is quite possible that they may have "thinned out" in the centre of the basin. Nothing is more characteristic of these beds in Scotland than their irregular mode of occurrence. They thicken and thin away rapidly, and the same may be the case with the Langness beds. On the shore, at the Grenea Point at low water, the lower limestones dip 5° N. of E. at an angle of 10°–12°, and about a hundred yards or so to the west the schistose Silurian shales occur. The latter are well exposed at the "Black Rocks." The junction between the two formations is not seen, for the intermediate space is covered with gravel. South of Strandhall at low tide the lower limestones are visible, having the same easterly dip at the same gentle angle. Close to the point where the Strandhall Burn enters the sea, a fault runs along the foot of the "Travertin Cliff." The direction of this fault is 12° E. of N., and the downthrow is to the east. Still farther eastwards there is another fault, whose direction is 6° W. of N., with a downthrow in a similar direction. The two conjoin and form a main fault, the effect of which is well seen on the shore south of Poyll Richie. The beds on the east or downthrow side are nearly vertical. On the west side they are considerably broken, but not many yards off they dip 6° S. of W. at a gentle angle. This fault cuts off the top part of the Lower Limestone series, and brings on immediately the members of the upper or Poolvash limestone group.

A small outlier of the lower limestones appears at Port St

* See "Isle of Man," p. 143.

Mary. The beds are there seen dipping away from the schists at a low angle, the general direction being S. 17° E.

In these various localities the series is characterised by the presence of thick beds of limestone, alternating with dark blue shaley partings. As a rule, these limestones weather with a yellowish brown colour, like the "dun" limestones near Shap. The same fossils have been obtained by Cumming from these points, which will be referred to in the sequel.

2. *The Upper or Poolvash Limestone Group.*

This group occupies the centre of the trough, and occurs in the neighbourhood of Poolvash. It is exposed on the shore, on Balladoole Hill, and in the fields east of the Black Marble Quarry. The relation between this group and the lower portion of the series is not very clear. Between the Poyll Richie fault above referred to and the point where the upper limestones occur, the beds are so much smashed that no bedding is distinguishable. In the bay west of Balladoole House they dip S.E., and roll round in the direction of 10° W. of S. At Ghaw Gortagh they alternate with dark calcareous flags and shales, which are evidently the lowest beds of the "Black Marble Group." The beds in this portion of the series are distinguishable by their white colour, and, as Cumming has proved, by their fossils.

3. *The Poolvash Black Marble Beds* (*Cumming's Posidonia Schist*).

These beds occur only in the neighbourhood of Poolvash, and have but a partial development. Lithologically, they are distinct from the underlying groups, and imply a change in the physical conditions which existed during the time of their formation. In the quarry south of Poolvash, where they have long been worked, the beds consist of black shales and black calcareous flagstones, varying in thickness from 6 to 18 inches. They dip nearly west, but north and south of the quarry on the shore they roll about. In these beds there is a strange intermingling of forms. Ferns and calamites are associated with true marine organisms, in such a way as to lead one to the conclusion that land must have been near the place of deposition. On the shore at the mouth of the Poolvash Burn they are interstratified with thin white limestones, which resemble the limestones of the underlying group. At this point also the beds are thrown into a series of gentle synclines and anticlines, the tops of which are worn away in places, exposing the rocks underneath. Contemporaneous volcanic rocks are associated with the members of this series, as I shall point out presently.

Having briefly described the representatives of the Carboni-

ferous Limestone series as developed in the Isle, it is now essential to correlate them with members of the same series in other regions. From their general character it is evident that the Manx rocks have a much greater affinity to the English than the Scotch series. Cumming's work helped to throw light on this question. His residence in the Isle gave him ample opportunity for making a good collection of fossils. His list gives upwards of 222 species, determined partly by Phillips, Sowerby, Keyserling, Ansted, Gilbertson, &c.* In his last publication he correlates the lower or Castletown limestones with the lower scar limestone of Professor Phillips; the white limestones with the upper scar limestone of Yorkshire, and he considers that the Posidonia schist has "no exact equivalent in the British Isles."† From the manner in which the black shales and flags are interbedded with bands of white limestone, it occurred to me that they really belonged to the close of the white limestone group, though implying different physical conditions. If it be true,‡ as Cumming infers from the nature of the fauna, that the white limestones were deposited in shallow water, then it might quite well have happened that the change from the one set of conditions to the other was a gradual one. But, further, the fact that the black marble beds, which are in all probability estuarine, being interstratified with the white limestones, seems to point out an alternation of the conditions under which they were deposited. Slight elevations and depressions no doubt intervened.

Mr R. Etheridge, jun., F.G.S., has kindly furnished me with the following note on the fossils found in these beds:—

"Of the 36 species of animals mentioned by the Rev. J. G. Cumming as characteristic of his Posidonia schist, we may eliminate 3 species as undetermined, 2 of doubtful determination, and 7 new species created by the author himself, and which from a stratigraphical point of view prove nothing. This leaves 24 good species, of which 22 are characteristic carboniferous limestone forms. The two remaining species, *Posidonia Becheri*, Phill., and *Posidonia literalis*, Phill., are more particularly representative of the upper limestone shales and Yoredale rocks, that groups of shales, grits, and fine sandstones, which in central England intervene between the true carboniferous limestone group and millstone grit. It is to the horizon of the upper limestone shales that the Posidonia schist is probably referable. Some few of the above 22 limestone species have been met with in the Coal Measures, but only under exceptional cases and conditions."

* See "Isle of Man," p. 354.
† See "Guide to the Isle of Man," 1861, p. 160.
‡ See "Guide to the Isle of Man," 1861, p. 161.

Igneous Rocks.

a. Interbedded or Contemporaneous.

Perhaps the most important feature connected with the carboniferous rocks of the Isle is the occurrence in them of contemporaneous volcanic rocks. Cumming long ago pointed out the existence of "felspathic ash," and the fact of its being associated with the Posidonia schist;* but he failed to note the bedded porphyrite which overlies the ash, and he associated with the carboniferous volcanic rocks certain basalt dykes which are certainly post-carboniferous.† These rocks occupy a narrow strip along the shore about two miles in length, from the Stack of Scarlet to Poolvash. It will be advisable to describe, first of all, the rocks in the neighbourhood of Poolvash, as these occupy the farthest limit from what seems to have been the centre of eruption.

On the shore, opposite the farm-house at Poolvash, fine trap tuff is seen resting on the white limestones associated with the black flags. Here the ash "tails off," and does not occur to the west. In the bay, where the highest group has been thrown into a series of gentle folds, the ash is worn off the tops of the arches, and the black flags are exposed. About forty yards south of the marble quarry the trap tuff rests on the black marble beds, which dip W. 6° S. at from 15°–20.°

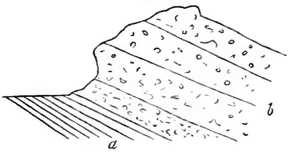


Fig. 3.—*a.* Black marble beds.
b. Fine trap tuff.

At this point there is a small syncline, containing a "nose" of the ash.

Fig. 4.—Ground plan showing small folds in the ash and black marble beds.

A few yards south of this fold, the black marble beds are

* "Isle of Man," p. 122.

† "Isle of Man," p. 244.

found to be interbedded with the trap tuff. Some thin lenticular bands of black flags and shales, varying in thickness from

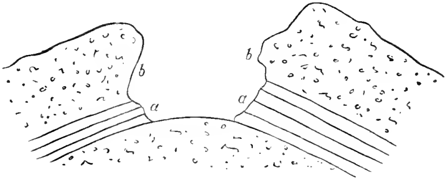


Fig. 5.—*a*. Black marble beds interbedded with the ash.

3–5 feet, are overlaid and underlaid by the ash. The beds are thrown into a gentle arch. The top of this arch has been denuded, and the underlying ash is exposed.

In the Bay, at Close-ny-Chollagh Point, the following section is exposed:—

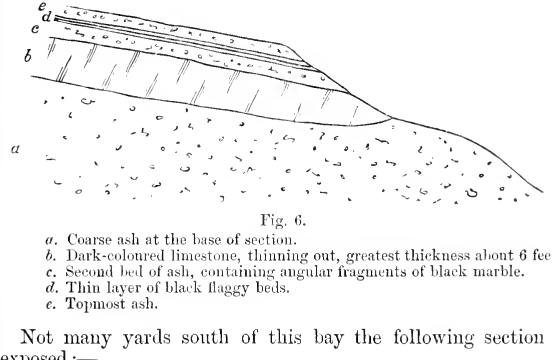


Fig. 6.

a. Coarse ash at the base of section.
b. Dark-coloured limestone, thinning out, greatest thickness about 6 feet.
c. Second bed of ash, containing angular fragments of black marble.
d. Thin layer of black flaggy beds.
e. Topmost ash.

Not many yards south of this bay the following section is exposed:—

a. Fine ash, well stratified at the base.
b. Well-bedded ashy and sandy bands, splitting in laminæ about an inch thick.
c. A bed of dark calcareous flagstone.
d. An irregular bed of ash.
e. A bed of finer ash caps the section.

All the beds dip 3° S. of W. at from 8°–10°. From these sections it is evident that the trap tuff is really interbedded with the black marble beds. The volcanic discharges must have

been intermittent, so as to allow time for the deposition of the flagstones, and the formation of beds of limestone. The ash is generally fine in texture, and of a greenish colour. It extends all along the coast line to the Stack of Scarlet, but at this locality it changes its character. On the whole, it is well bedded, with a westerly dip. In many places the sea has formed stacks of the ash, and by this means fine sections upwards of 30 feet in depth are exposed.

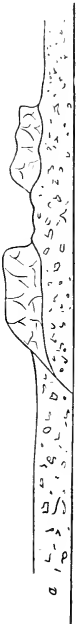


Fig. 7.—a. Ash faulted down against porphyrites.

Knobs of porphyrite occur in the fields east of Close-ny-Chollagh Point. A little way south of the fort, on the shore, it is seen capping the ash. Again, close to the ruin, near the old burying-ground, the porphyrite occurs. The trap has a compact grey felspathic base, and is very amygdaloidal, the cavities being well seen on weathered surfaces. South of the old burying-ground knoll a fault brings down the ash against the porphyrite, the direction of which is about 30° N. of W. Eastwards, on the shore, the fault is still better seen, and runs out to sea about 200 yards west of the stack. At this point the trap is thrown into a small arch, the top of which is denuded, and the underlying ash exposed.

Where this section occurs blocks of trap and limestone, upwards of 3 feet and 4 feet in length respectively, are embedded in the ash. From this point, eastwards towards the Stack of Scarlet, the ash changes its character, and passes into a coarse volcanic agglomerate. The large blocks vary in size from 1–4 feet in length, and are very abundant. Those of trap and fossiliferous limestone frequently occur. Alongside of Cromwell's Walk the coarse agglomerate abuts against the truncated edges of the lower limestones, which are bent in towards the ash at the line of junction. This is one of those peculiar vertical junctions which are so characteristic a feature of the carboniferous volcanic areas of Scotland. There are only two ways of accounting for a junction of this kind: it is either a fault or the side of an old volcanic orifice. A few yards north of the Stack of Scarlet the beds are much broken and altered along the junction line. At this point a portion of the white dolomitic limestones appears pressed in between the truncated edges of the lower limestones and the agglomerate. This detached mass has yielded to Cumming fossils characteristic of the white limestone group.* Here

* See "Isle of Man," p. 126.

the junction resembles the irregular edge of an old volcanic neck, and it is highly probable that this may be the explanation of the junction line alongside of Cromwell's Walk.

The coarse agglomerate is pierced by an intrusive dyke of compact greenish trap, which terminates in the Stack of Scarlet. The stack is entirely formed of this material, and on the top and south sides the prismatic columns are well developed. They are of a polygonal shape, and, as a rule, are vertical. This intrusive mass traverses the agglomerate for a distance of a hundred yards or so from the stack to the point where an isolated patch of porphyrite rests on the ash. The sides of the dyke are, on the whole, perpendicular, though in some places they slope inwards. In the centre of the mass the rock is compact, but towards the edges it becomes coarse and amygdaloidal, with the cavities flattened or drawn out. Professor Geikie, who has seen a specimen of this rock, considers that it approaches most nearly to the character of a diabase. This intrusive mass has no connection with the basalt dykes in its vicinity, as Cumming supposed, but belongs in all likelihood to that period of volcanic activity when the lavas and ashes were erupted.

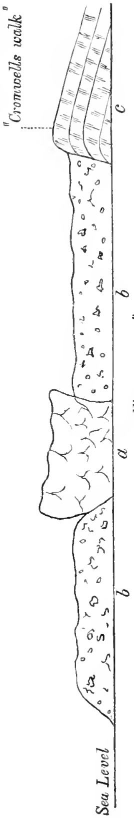


Fig. 8.

a. Intrusive diabase in volcanic agglomerate—Stack of Scarlet.
b, b. Coarse volcanic agglomerate enveloping dyke.
c. Lower limestones with their truncated edges bent in towards the agglomerate.

It is common to find the volcanic agglomerate of the Scotch "necks" pierced in this manner by intrusive plugs of igneous rock, such as basalt and felstone.

This small area of contemporaneous trap rocks acquires an additional value from the fact that proofs of volcanic activity are rare in the Carboniferous series of England. Beds of trap and ash occur at the base of the series in Cornwall and South Devon.* Professor Jukes proved also that the toadstones of Derbyshire are truly interbedded with the Carboniferous limestones.† At the last

* De la Beche, "Devon and Cornwall," p. 122.
† Manual of Geology (Jukes), 2d ed., p. 523.

meeting of the British Association, Mr Topley, F.G.S., and Mr Lebour, F.G.S., of the English Geological Survey, read a paper on the Whinsill of Northumberland, hitherto considered by many to be contemporaneous. They conclude "that the whinsill is intrusive, and has been forced in a melted state through the rocks long after their deposition and partial consolidation."*

The occurrence, then, of volcanic rocks in the Isle of Man becomes a matter of importance, since it proves the existence of volcanic action during the deposition of beds which are probably on the same horizon as the upper limestone shales of England.

b. Intrusive or Subsequent.

Dykes.—The usual felstone dykes traverse the Silurian rocks, but are not met with in any of the later formations. A well-marked series of basalt dykes occurs in the south side of the island. These dykes cut through all the stratified rocks from the Skiddaw slates up to the trap-tuff. They occur in various localities —at Skilicore, at Langness, South of Castletown Harbour, near Scarlet Point, in the ash on the shore west of Cromwell's Walk, in the ash and black marble beds at the Poolvash black marble quarry, &c. They run in an east and west direction. They are of a dark and dull gray colour, with a texture varying from compact to granular. Crystals of olivine are abundant, and kernels of tachylite sometimes occur near the edges of the dykes. They belong, in all probability, to that great series of basalt dykes in the south of Scotland and north of England which Professor Geikie has proved to be of Miocene age.

Granite.

One mass of granite occurs at the Dhoon, north of Laxey, and another near South Barrule, but to these I paid no special attention. Cumming pointed out in 1848 that no fragments of granite had been found in the Langness conglomerates. From this fact he inferred that these granitic masses were not exposed to denudation in lower Carboniferous times.†

The Glacial Phenomena of the Isle.

The glacial deposits of the Isle have long been a subject of interest to geologists. This arises partly from the fact that certain members of the drift series reach a development in the north end of the island which can hardly be equalled elsewhere. On the north side of the chain of high ground upwards of 50 square miles are covered with drift deposits, continuous sections of which are exposed from Ramsey to the Point of Ayre, and

* See "Nature," No. 205, vol. viii. † "Isle of Man," p. 239.

thence to Kirkmichael, a distance of 23 miles. Although Professor Edward Forbes examined these cliff sections, and even named the shells obtained from the beds, yet I am not aware of any special paper which he wrote on the subject. The interesting facts noted by him are embodied in his classic paper on "The Fauna and Flora of the British Isles." In his various publications Cumming referred to the striations and superficial deposits of the Isle, giving a general classification of the drifts. He went further, and tried to prove that the whole series might be satisfactorily accounted for by the iceberg hypothesis. His writings show that he was to some extent influenced by the "waves of translation."*

So far as I know, Professor Geikie was the first to attack boldly the iceberg theory, and to point out its insufficiency to account for all the phenomena.† In his papers on "The Physical Cause of Glacial Climate," Mr Croll has likewise endeavoured to demonstrate that too much has been attributed to iceberg action, and that icebergs are in reality incapable of producing the results which some have supposed.‡ More recently, Mr James Geikie, F.R.S.E., in his volume, "The Great Ice Age,"—a book which marks an epoch in the history of glacial geology,—has exposed the absurdities of this hypothesis.§

Those who still cling to this theory ignore two points. They seem to overlook the fact that the striations on the land radiate from the main mountain ranges, and they forget also that the various members of the drift series imply totally different physical conditions. These facts can be explained only by the theory first propounded by Agassiz, that the whole country was covered by land ice. It is now generally believed by those who have studied the subject, that one great sheet of ice enveloped the land from the highest peaks to the sea level. The occurrence of striations passing underneath the waterlip, and the fact that *roches moutonnées* are met with in the western fjords, have hitherto been accounted for by supposing that the land was relatively higher during the glacial period than it is now. In other words, the sea lochs on the west coast were believed to be submerged land valleys. In his recent volume Mr James Geikie reverts to this supposition, and clearly shows that the ice sheet must have been so thick as to "dispossess the sea in all the sounds, straits, and channels that separate the islands from themselves and the mainland." He adduces the glaciation of Lewis in support of this conclusion. This island is glaciated from south-east to north-west. The land ice which crossed it must have come from

* "Isle of Man," p. 249.

† See Professor Geikie's paper on "The Glacial Drift of Scotland."

‡ See Mr Croll's paper on "Geological Time," Phil. Mag., Nov. 1868.

§ See "The Great Ice Age."

Ross-shire, a distance of 30 miles, and filled up the Minch which intervenes.*

The glacial phenomena of the Isle of Man furnish a remarkable confirmation of the above generalisation, the direction of the striæ, as well as the superficial deposits, distinctly proving that the island has been overflowed by glacier ice.

Glaciation of the Low Grounds of the Isle.

Nearly thirty years ago, when advocating the theory of enormous waves, Cumming pointed out the marked contrast between the eastern and western sides of the island as proving the influence of such action.† The truth of this observation, apart from the inference, is patent to every glacialist when approaching the Isle by steamer. The hills which constitute the backbone of the Isle have a smoothed and mammillated face on the north-east side. Although this feature is not so apparent when traversing the high grounds, yet, in spite of the scarcity of striæ, the Skiddaw slates present those planed features which are so characteristic of glacial action. The striæ recorded by Cumming are "very nearly magnetic east and west."‡ The following are the instances I noted:§—

At the Scarlet limekilns, on the west side of Castletown Bay, well-marked striations occur on a planed surface of limestone, rising from underneath the waterlip, and passing below a deposit of till. The direction is W. 27°–30° S., the latter being common. A few yards north of this, on a broken surface of limestone, the striæ run W. 37°–40° S. There are faint traces of a newer set, with a direction of S. 37°–42° W. Again, on the top of the black marble beds in the quarry at Poolvash, the direction of striation is W. 40° S. At Port St Mary, near the wood-work, they run W. 32° S., on a bed of limestone, and some newer striæ strike S. 28°–32° W. The main set, which are very well marked, have the former direction. At the limekilns well-marked groovings are seen tending W. 34° S., and again on a well-glaciated surface, after turning the point south of the kilns, the direction is S. 35°–37° W.

Now, it is hardly necessary to point out that these markings cannot be accounted for by any mere local glaciation. The chain of high ground crosses the island in a north-east and south-west direction, and the general trend of these markings is parallel to this axis, or nearly so. Had the island been glaciated from its centre to its circumference, the *ice flow* would, as a rule, have been at right angles to the *ice shed*, and the striations would

* See Quart. Jour. Geol. Soc. Nov. 1873.

† See "Isle of Man," p. 249.

‡ See "Guide to the Isle of Man," p. 165.

§ Some of these are recorded by Cumming.

therefore have followed in a similar direction. But the reverse is the case. We can only account for the phenomena by inferring that the Isle was glaciated by ice from the mainland.

The Till and Boulder Clay with Interglacial Beds.

The Isle of Man, as I shall presently show, contains representatives of these members of the drift series. In various localities a deposit occurs in all respects identical with the true lower till of Scotland. If toughness of texture, and a thoroughly unstratified arrangement with well-striated stones, are indices of true till, then the oldest superficial deposit of the Isle has a claim to be ranked under this category. The first section I will note occurs at the Scarlet limekilns. On the top of the glaciated limestones rests a deposit of till only a few feet thick, capped by a thin layer of gravelly earth. The till is of a yellowish brown colour, and every stone embedded in it has well-marked groovings. They consist chiefly of limestone, white quartz, quartz rock, with some pieces of fine-grained granite, and schist, and even a few coarse-grained grits,—the last of which Cumming suggested as having probably come "from the shores of Cumberland and the south of Scotland." *

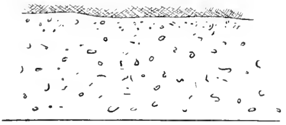


Fig. 9.—Section of till at Scarlet limekilns.

About 200 yards west of "the mass of travertin," and again close to the Strandhall farm-house, on the shore, similar sections of true till are exposed.

Near the wood-work at Port St Mary, on the shore, a deposit caps the striated limestones which resembles in every respect the true till. It contains fragments of limestone, quartz, quartzite, schist, all of which are well scratched. This deposit is overlaid by well-stratified beds of gravel. Again a similar deposit is met with at the limekilns only, about 5 feet thick.

In the Silver Burn, nearly due south of Grenaby farm-house, the following section occurs. (See fig. 10.)

This section forms the south bank of the stream, and rises with a steep slope from the water's edge.

a, A deposit of stiff stony clay, extremely tough, varying in colour from dark blue to yellow, from 20 to 30 feet thick. The stones consist of granite, white quartz, quartzite, grey schist, shales, and felstone porphyry, and nearly all have well-striated surfaces. This is unquestionably true till.

b Is a layer of loam and fine lapilli, about 15 inches thick, at the right hand of section, and thickening gradually to 2 feet.

* See "Isle of Man," p. 120.

This deposit rests on an eroded surface of the till, and the layers of stones are stratified down the course of the stream.

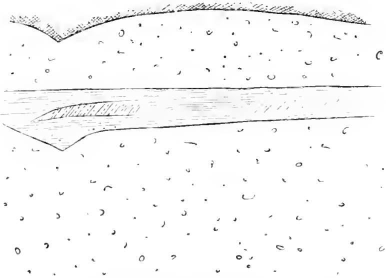


Fig. 10.—Section showing interstratified layers of fine sand and small stones in till.

c Is an upper layer of stiff stony clay, very like the lower, from 2 to 3 feet thick. The stones are well scratched, and resemble in character those of the lower till.

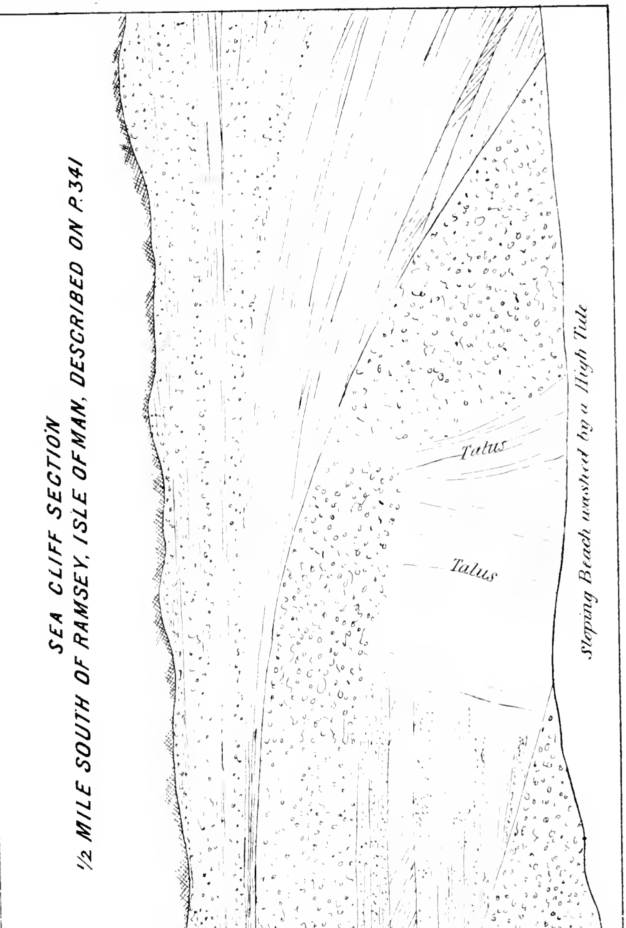
In several localities on the south side of the island deposits occur which more closely resemble the boulder earth or maritime boulder clay of Scotland. One notable instance is to be found at the black marble quarry, where the beds are overlaid by an earthy clay with large subangular stones. Again, in the Ballasalla quarry the limestones are capped by a boulder earth not unlike the upper boulder clay. In the lower part of the section it consists of an earthy clay with large subangular blocks. Higher up, the deposit is not so coarse, and the stones are pretty well scratched, consisting of granite, schist, white quartz, liver-coloured quartz rock, and grey sandstone. At Peel, in the railway cutting below Glen Faba bridge, some thin beds of sand, with small stones resting directly on the blue schists, are overlaid by a sandy boulder clay containing scratched stones. This upper boulder clay is covered with gravel, which in all probability belongs to the kame series.

In the streams which run into the sea between Peel and Kirkmichael, excellent sections of the lower boulder clay and overlying deposits are exposed. In Glen Mooar, just below the high road between Peel and Kirkmichael, and close to the point where it enters the sea, the following section occurs. (See fig. 11.)

a, Finely stratified sand exposed in the lower part of section, from 6 to 8 feet thick. The bottom of the sand-bed is not seen, its relation to the underlying deposit being obscured by a talus of drift.

b, On the sand rests a deposit of stony clay, varying in tint

SEA CLIFF SECTION
½ MILE SOUTH OF RAMSEY, ISLE OF MAN, DESCRIBED ON P. 341



from blue to yellow, and of a very tough texture, and about 20 feet thick. The stones are distinctly scratched, and consist of schist, blue greywackes, white quartz, and one or two chalk flints. The larger blocks have the best preserved markings. This strongly resembles true till.

c, Stratified sands and gravels, from 8 to 10 feet thick, cap the section. These in all probability belong to the kame series.

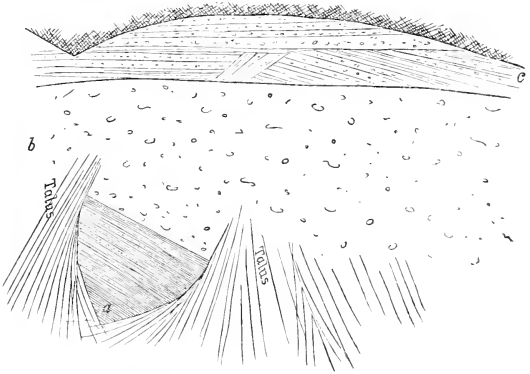


Fig. 11.—Section of till resting on fine sand, capped by stratified sands and gravels, Glen Mooar.

Again, in the Sulby Glen, close to the village of Sulby, a good section of till is exposed on the banks of the stream. The boulder clay changes its character further up the glen, becoming more earthy, and the stones more subangular.

About half a mile south of Ramsey, at the point where the Ballure Burn joins the sea, the following important section (of which a lithograph is annexed) is seen on the shore.

a, At the left-hand corner of the section occur the gnarled Skiddaw slates, much broken and smashed along their upper edges. A thin layer of clayey matter and rock debris steals over the edges of the slates.

b, Overlying this rock debris is a stiff stony clay of a bluish colour, and extremely tough. The stones are well scratched, and their angular edges have been planed off. No large boulders occur in this deposit, the average size never exceeding more than a few inches. In this deposit I found the following rocks—blue slates and shales, white quartz, small specimens of

Criffel granite, and fragments of a dark trap rock, pink porphyritic felstone, chalk, chalk flints, clay band ironstone, and small pieces of brick-red sandstone (Permian). This is undoubtedly the representative of our Scotch till. Its thickness is about 12 feet.

c, The till is overlaid by a series of finely-stratified sands and gravels, which contain nearly the same foreign rocks, evidently a marine deposit. These stratified sands are from 8 to 10 feet thick, thinning out, however, to the left-hand side of section. They seem to rest on an eroded surface of the till.

d, These sands and gravels lie underneath another deposit of stony clay, from 6 to 8 feet thick, which differs in a marked degree from the lower till. In this deposit scratched stones are not so abundant as in the former, and on the whole they are more angular, but the matrix is tenacious. Its general character harmonises more with the Scotch maritime boulder clay.

e, This boulder clay is capped by a series of well-stratified sands and gravels, the highest beds in the section. They evidently rest on an eroded surface of the boulder clay, and pass upwards into that great series of sands, gravels, and shelly clays which form the cliffs from Ramsey to the Point of Ayre.

Inferences deducible from the foregoing Data.

How, then, are these various facts to be accounted for? The striæ prove that the agent which produced them was independent of the Isle—their direction being determined by no mere local causes. The above sections also show that the till is in all respects similar to our own Scotch till,—a product of land ice. There is abundant evidence, too, of a strange intermingling of foreign rocks in the till, which must have travelled from the coast of Cumberland, the south of Scotland, and the north of Ireland. These facts seem to indicate that the Isle of Man was glaciated by ice from the mainland. It is worth noting how this conclusion tallies with the results already obtained from a consideration of the glacial phenomena in Cumberland, the south of Scotland, and the west coast of Ireland.

During the progress of the Geological Survey, my colleague, Mr H. M. Skae, has proved that the ice-sheet in Eskdale and Annandale moved in a southerly direction. Between the Dee and the Nith I have gathered evidence to show that the ice had a south-east trend, and passed into the Solway Firth in the direction of the Cumberland coast. From the fact that Scotch rocks occur in the vicinity of Cockermouth, it is evident that the Scotch ice must have impinged on that coast-line. This is not

to be wondered at, for during the past year my investigations in Galloway led me to the conclusion that the ice-sheet at the mouth of the Nith must have been at least 2000 feet thick. On the south side of Criffel I found till at a height of 1500 feet, and smoothed greywacke stones, which had travelled for miles at a height of nearly 1800 feet, evidently the relics of the till.

Again Mr Ward, F.G.S., in his paper on the glaciation of the Lake district, has clearly proved the existence of "a great confluent glacier sheet, at one time almost completely enveloping a great part of the Lake district. The movement of this ice-sheet was determined by the principal watershed of the Lake district, running through its centre approximately east and west."

The Scotch and north lake ice, meeting face to face on the Cumberland coast, must have taken a resultant direction, viz., towards the *south-west.* The soundings in the firth between the Isle and Cumberland nowhere exceed 30 fathoms, and the ice, therefore, must have moved over the bed of the Solway much in the same way as over a low-lying plain. By this method the Manx striæ are to be accounted for, and also the presence of Scotch and English rocks in the till.

Again, my colleague, Mr D. R. Irvine, has shown that the low grounds of Wigtonshire were covered with one vast glacier, which moved out to sea in a *south-westerly* direction.* Mr James Geikie has ingeniously explained the deflection of the striæ on the north coast of Ireland by supposing that the Scotch ice impinged on that coast-line; and the two streams thus uniting, the one part was turned off in a north-westerly direction, and the other part to the south-east.† In Mr Close's glacial map of Ireland the striæ run in a south-east direction from Belfast Lough to Carlingford Bay. From this point to the Skerries, south of Drogheda, the glacial trend of the markings and drift ridges is more easterly, while south of Dublin Bay the direction is nearly south-east. He states that "the universal glacier was probably not less than 3000 feet in depth."‡

Now, it is highly probable that this great mass of Irish ice succeeded, after a hard battle, in reaching the Manx coast-line. It is not to be supposed that the normal momentum of the respective ice-sheets remained constant. The moving force must have varied with changing conditions. On the other hand, it is quite possible that there may have been an "undertow" of the ice from the north-west coast of Ireland, which would easily account for Antrim chalk, and chalk flints in the Manx till. At any rate, the respective ice-sheets must have been subjected to intense compression, and consequently there would be a com-

* See Explan. to Sheets 1, 2, 3, Geol. Survey.
† See "The Great Ice Age," p. 522.
‡ Geol. Mag., May 1867, p. 234.

mingling of the *moraine profonde* in the bed of the Irish Channel. But further, this constriction of the ice in the Irish Channel must have had a denuding effect on the ocean bed; for the greater the constriction, the greater would be the pressure, which means increased scooping power. Mr James Geikie, in his recent volume, has worked out this idea most successfully. He has published a map showing the number of submarine hollows which would appear on an elevation of the land to the height of 600 feet. He arranges them in two groups, viz., "fjord" and "deflection basins." The submarine hollow in the Sound of Jura is a good instance of the former, and the basin in front of the island of Rathlin is a good instance of the latter.* These submarine basins are analogous to the rock basins on the land, for they have been formed in the selfsame way.

Now, in the centre of the channel between the Portpatrick coast-line and the Irish coast, a glance at the Admiralty chart is enough to prove the existence of a great basin. The 80-fathom contour line forms the rim of this hollow, and its greatest depth is 149 fathoms. This gives a maximum depth of 69 fathoms (414 feet) for the rock basin. It occupies the centre of the channel from Corsewall Point to the Mull of Galloway.

Again, between Anglesea and Caernarvonshire on the one side, and the coast-line from Dublin to Wicklow Head on the other, there is another well-marked submarine hollow. The 55-fathom line forms the rim of this basin, and its maximum depth is 84 fathoms. This gives a depth to the basin of 29 fathoms or 174 feet.†

It is worth observing that the basins which are indicated on the Admiralty chart appear precisely in those localities where, according to the theory advanced by Professor Ramsay, they ought to occur. I have already pointed out that the ice which occupied the Irish Channel attained a thickness exceeding 2000 feet, and that this vast ice-flow, as it passed out to sea, was continually receiving fresh accessions from the ice-fields of the three kingdoms. Now, it is self-evident that this enormous mass would not only displace the sea, but would erode the sea-bottom in precisely the same manner as it scooped out hollows in the land. Wherever, therefore, the conformation of the sea-bottom and adjacent lands was such as to obstruct and constrict the ice-flow, *there* excessive erosions would result. And no one who examines the direction of the glaciation of north-eastern Ireland, southern Scotland, and north-western England, can doubt that there must have been excessive erosion in the very places where the Admiralty chart points out that deep rock basins exist.

* "The Great Ice Age," p. 519, *et seq.*

† See chart of East Coast of Ireland with the Irish Channel, from surveys by Captain Beechey.

The above sections seem to me to prove the existence of interglacial periods prior to the great submergence. Some of these beds of sand and gravel are undoubtedly marine, because they contain foreign rocks. Still, their occurrence points to a retirement of the ice-sheet and the prevalence of milder conditions. The existence of beds of sand and gravel in Scotch till was first pointed out by Professor Geikie.* More recently, Mr James Geikie has correlated the Scotch and English glacial drifts, and brought forward much striking evidence to show that those ancient cave deposits and river gravels of England which contain extinct mammalia and relics of man, are contemporaneous with the interglacial deposits of Scotland.† If this conclusion be true, as the evidence seems to warrant, then these interglacial beds, scanty though they be, are of great importance. I have no doubt that a detailed survey of the island will prove the existence of not only one, but several interglacial periods prior to the submergence. As the wave of cold increased, the ice once more advanced, and the upper boulder clays were formed. It is highly probable that marine organisms will be found in the Manx boulder clays, just as in the case of the Caithness boulder clay.

Sands, Gravels, and Shelly Clays.

Kame Series.—The deposits belonging to the period of great submergence are well developed in the island. Cumming notes the occurrence of gravel at a height of 400 feet on the Calf of Man.‡ This series is met with in the valley between Peel and Douglas. I traced it along the western slopes of the hills from Peel to Kirkmichael, and thence to Ballaugh. Behind the village of Kirkmichael, on the right and left sides of Glen Wyllin, the gravels are heaped up into great mounds. This was the most remarkable instance of the kamiform structure I met with.

Shelly Clays, and stratified Sands and Gravels.—The series of deposits which deserves special mention is that which occupies the plain called the Curragh, upwards of 50 square miles in extent. The coast-line from Ramsey to the point of Ayre, and thence to Glen Mooar, near Kirkmichael, exposes a continuous section of these beds. These beds have been described by Strickland, and they are frequently referred to by Forbes in his great paper. No more accurate description of this series could be found than the terse one given by Forbes in the paper referred to. " In the Isle of Man, the marl-beds containing bivalves of the second or third region in depth, are capped by a great thick-

* See "Glacial Drift of Scotland," p. 53, *et seq.*
† See "Great Ice Age," p. 355.
‡ See "Guide to the Isle of Man," p. 97.

ness of sands and gravels, occasionally containing littoral shells, but rolled. On these sands the larger boulders usually lie."* Such is the *general* appearance of the coast section from Ramsey to the Point of Ayre, and thence to Glen Wyllin. As a rule, the shelly brick clays lie at the base of the cliffs, but it is not always so. Shells are plentiful in the brick clays. Mr R. Etheridge, jun., has favoured me with the following note on the list of glacial shells published by Cumming, and named by Forbes:—†

"The list of glacial shells given by the Rev. J. G. Cumming appears on the whole to agree with those commonly met with in our Scotch glacial clays. One or two species, however, deserve notice. The shell mentioned under the name of *Pectunculus pilosus* is not, so far as I am aware, usually found in our glacial beds. The *Astarte pisiformis*, S. Wood (=*A. Burtinii*, Lajonkaire), is a coralline and red crag species, and is not mentioned as a glacial shell by the late Edward Forbes in his great paper (Mem. Geol. Survey, 1.) *Nassa monensis*, Forbes, is also a red crag shell."

The cliffs at the base of which the shelly clays usually occur, vary in height from 50 to 200 feet. The upper stratified gravels which cap the marls, as noticed by Forbes and Cumming, contain boulders of foreign rocks of such a size as to lead one to believe that icebergs must have been drifting in the sea during the time of their formation.

Moraines.—There can be little doubt that local glaciers existed in the Isle towards the close of the great submergence. One would naturally expect to meet with traces of moraines in the upland valleys, as the general configuration of the ground seems favourable to the development of a local system of glaciers. I ascended most of the valleys on the north side of the range, but found no well-marked moraines. I found some sections of loose rubbishy moraine-like matter, with few scratched stones which might serve to mark the shrinkage of the ice back into the corries. My acquaintance with the upland valleys is not so minute as to enable me to say that there are no well-marked moraines in the Isle.

After the great submergence, as Forbes has shown, the Isle was joined to Ireland and England, and the shores of England were united to the Continent. Across this land passage the Germanic fauna and flora slowly migrated to western climes.‡ Mr James Geikie has ingeniously suggested that this great elevation marks the beginning of the Neolithic age, and that the period of great submergence represents the break between Palæo-

* Mem. Geol. Sur. vol. i. p. 385. † "Isle of Man," p. 360.

‡ See "Fauna and Flora of the British Isles," Mem. Geol. Sur. vol. i. pp. 358 and 393.

lithic and Neolithic times.* Whatever may be said against this hypothesis, it certainly gives a feasible explanation of a break which was previously unintelligible. It was then that the *Cervus megaceros* roamed over the wide plains, whose remains are dug up from the fresh-water marl pits in the Curragh of the Isle.† The growth of forests immediately ensued, and as the depression of the land increased and the continental conditions once more vanished, the forests yielded to the life-destroying influences of climatic change. The submerged peat-bed containing trunks of trees south of Strandhall, visible at low tide, is convincing proof of the great range of these old forests. Again the forces of upheaval asserted their sway, and the flat terraces which fringe the coast-line were slowly carved out. These old sea-beaches mark the close of the interesting series of geological changes in the Isle of Man.

* Great Ice Age, p. 484, *et seq.* † See "Mem. Geol. Sur." vol. i. p. 394.